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SOME STRATIGRAPHIC AND STRUCTURAL FEATURES OF THE PRE-CAMBRIAN OF NORTHERN QUEBEC

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PART III

CORRELATION

In this region, where the sedimentary series do not form any large or continuous sheet, but are found merely as comparatively small remnants separated by wide areas of intrusive granite, it is obviously impossible to make an unquestionable correlation. If in some yet unexplored district there should be found large continuous sheets of sediments which might serve as definite horizon markers over a large area, as the Cobalt series does in the Cobalt-Sudbury-Lake Huron district, a good correlation may eventually be obtained. But under present conditions the criteria on which we must rely for correlation purposes are (1) petrographic similarities; (2) similar geological successions; (3) similar deformations; (4) similar relations to older and younger formations.

PONTIAC-MATTAGAMI-BROADBACK-BROCK SERIES

The patches of sediments known at present under the local names Pontiac, Mattagami, Broadback, and Brock series have strong petrographical similarities. In each the principal rock is a schist which is probably the metamorphosed equivalent of a more or less impure sandstone or sandy shale. It is now composed of quartz and ferromagnesian mineral, with a little feldspar; the ferromagnesian mineral is usually biotite, which locally is replaced by muscovite or hornblende. The muscovite schist probably represents an originally fairly pure sandstone, and the hornblende schist a ferromagnesian sand. The more acid types may have derived their material largely from granitic sources, the more basic types from the basic lavas. The mica schists grade toward the base of the series into arkoses, greywackes, and conglomerates, which are of essentially the same composition as the schists above them, and differ only in their coarser grain.

This greywacke-like composition indicates that in each of the widely separated areas the sediments were derived by fairly rapid disintegration and erosion of older rocks, without extended decomposition of their constituents by atmospheric weathering. Had decomposition been complete and erosion slow, a better separation of the products of disintegration would have taken place, with resultant deposition of a normal sandstone-shale series. The band of quartzite found in the Kenoniska area is the only one observed in which fairly good segregation of the sedimentary material has taken place; yet its significance is not great, as the bed is thin and the quartzite very impure.

The petrographic similarities indicate that the sediments of the different areas were derived from similar sources, and that similar conditions of weathering and erosion were operative at the time each was laid down.

The succession of the different rock types also affords some evidence for correlation. At the base of each series is a conglomerate bed several hundred feet thick. The composition of this conglomerate is in every case similar—pebbles of granite and the underlying series of basic lavas, with their associated tuffs, cherts, and intrusives, imbedded in an impure sandy matrix. Above this, except in the Mattagami area, lies a coarse-grained arkose, greywacke, or grit, which passes upward into finer-grained material of much the same composition, now metamorphosed to mica schist. In the Mattagami area the conglomerate passes into the upper schist by a decrease in the size and number of the pebbles, without the intervening band of arkose; in the Kenoniska area a narrow band of impure quartzite lies between the arkose and the mica schist.

The succession is one which indicates an almost identical history of deposition in each of the areas under consideration. If the series is of marine origin, the history is one of deposition in a gradually deepening sea or of a subsidence of the land from which the sediments were derived. The absence of shale and limestone members in every case is also significant of the prevalence of similar conditions of deposition over the whole region.

Structural similarities form perhaps the best evidence for the correlation of these patches of sediment. Each area is a remnant of a close fold, and the amount of deformation during folding was approximately the same in all. On the flanks of the folds the whole body of rock has been converted into schist, even the competent basal conglomerate. The pebbles of the conglomerate in each case have been flattened and sheared, the softer stretched to mere strings, while the hard granites have suffered very little. The axes of the folds show remarkable similarity in strike. The general strike of the Pontiac area is east-west; of the Mattagami area, N. 80° E.; the axis of the Kenoniska and Lucky Strike folds strike S. 75° E.; of the Brock fold, N. 85° E. These variations in strike are very small, considering how widely the districts are separated from one another, and the conclusion therefore seems justifiable that all of these sediments preceded, and were deformed by, one period of regional stress. As the region has been gently cross-folded, the variations in strike most probably are due to this, though perhaps also in part to disturbance by the later intrusion of the granite batholiths.

The different patches of sediments are similar in their relations to the older lava series. In almost every case it has been shown that the sediments rest unconformably on the lava series, since the basal conglomerate contains rounded pebbles of all the underlying rocks. As to the nature of the unconformity, a close parallelism of strike and dip obtains between the two series, indicating either that they were folded at one time or that a possible earlier gentle folding of the lavas was obscured by more intense shear after the sediments were laid down. In the case of the Kenoniska and Lucky Strike areas, the basal conglomerate was observed to rest on different types of rock from point to point, but whether this was due to differential erosion of the underlying rocks previous to the deposition of the conglomerate or to original irregularities of deposition in the underlying series was not determined with certainty. It is believed, however, to have been due to erosion, since in the case of the Lucky Strike area the conglomerate at its most easterly observed contact rests upon garnetiferous mica schists, which are believed to be the metamorphosed equivalent of a once widely distributed sediment, the Nemenjish series, while farther to the west it rests directly upon basic lavas. In addition, the presence of the thick basal conglomerate indicates that the erosion of the underlying series was great before the deposition of the upper. In the undeformed conglomerate of the Kenoniska area, none of the basic pebbles possess schistosity; so that the lava series could not have undergone serious deformation before the conglomerate was laid down.

The similarity of the relations which prevail among the different patches of younger sediments toward the older series of lavas and sediments still further strengthens the probability that these patches originally formed part of a single widespread formation. The unconformity appears to be one of erosion mainly, with little or no structural discordance.

As regards the relations of the sediments to younger formations, the only younger rock in contact with all of them is the granite, which in each case intrudes them. As there is no sedimentary rock younger than the granite in the region, by which its age may be checked, the granite does not afford any adequate datum plane for correlation purposes.

Summary.—It has been shown that in the patches of sediments now known under the local names of Pontiac, Mattagami, Broadback, Lucky Strike, and Brock series, there are several striking similarities: (1) The character of the sediments shows that they were in each case derived by the disintegration and erosion of a land area, which went on with such rapidity that the component minerals of the eroded rocks were not highly decomposed; as a result, the sediments are not characterized by a normal sandstone-shale alternation, but are of a greywacke or arkose composition throughout. (2) The absence of the metamorphosed equivalents of limestone or shale, of which latter sediment there must have been some quantity, indicates fairly shoal water or subaërial conditions during the deposition of each series. (3) The succession in each case is similar; a conglomerate lies at the base, overlain by finer-grained material, arkose or greywacke, of essentially the same composition, which in its turn is overlain by biotite or hornblende schists, representing similar material in a still finer state of subdivision. The succession indicates a similar history in each case. (4) The relations of each body of sediments to the underlying lava series appears to be one of erosional unconformity; if structural unconformity also exists, the discordance is slight. Thus the period elapsing between the outpouring of the lavas and the deposition of the sediments was characterized in each case by gentle epeirogenic movements only, not by intense orogenic movement. (5) The close parallelism of the axes of the major folds of the different areas indicates that all were deformed either by the same force or by successive forces directed along the same lines; while a study of the effects of shear on the different folds shows that each body of sediment was deformed to about the same extent. These two lines of evidence indicate that all the sediments were folded at the same time, and by stresses of much the same strength. (6) All the sediments have been intruded by granites, which, though not proven to be of the same age, have not as yet been shown to be of different ages.

While, as previously stated, an entirely reliable correlation in these pre-Cambrian rocks cannot be made in the absence of a continuous sedimentary datum plane, nevertheless the foregoing evidence indicates such a uniformity in the history of these scattered patches of sediments that it appears highly probable that they are remnants of a single, once widely distributed formation or series. So far as now known, this series may have been deposited under marine conditions and have formed a continuous sheet, or under continental conditions in separate settling basins. As the time has not yet arrived for the correlation of these sediments with other ancient sediments to the south and southwest, such as the Timiskaming, Sudbury, and Hastings series, the writer would apply a single local name to all those under discussion, simplifying the nomenclature by the elision of the various local names already applied. The name Pontiac series, applied by M. E. Wilson in 1909 to the sediments of the first discovered belt to the south, has precedence; but in view of the doubt as to the composition of Wilson's Pontiac series, as outlined on page 200, the name "Mattagami series" will be used until the doubt is cleared up and the term "Pontiac" re-defined, if necessary. In the remainder of this paper the term "Mattagami series" will therefore be used to include the original Mattagami series, the Broadback, Lucky Strike, and Brock series, and the conglomerate-arkose portion of the Pontiac series to the south.

Age.—The Mattagami series has been shown to consist of scattered patches of sediments, all of which are older than a great orogenic movement and a period of granitic intrusion. In the southwest corner of the region under discussion, the Mattagami series is overlain by the flat-lying Cobalt series, which rests on a peneplain that bevels the Mattagami series, the intrusive batholiths of granite, and the older lavas indiscriminately. A very long period of erosion must have ensued therefore between the end of the deposition of the Mattagami series and the commencement of the deposition of the Cobalt series. The Cobalt series has recently been shown by W. H. Collins[1] to be of the same age as the upper part of the original Huronian series of the north shore of Lake Huron. It is separated there from the lower part of the Huronian, which Collins has termed the Bruce series, by an unconformity, represented by the erosion of some 1,600 feet of sediments and a gentle folding. The Bruce series has been shown by Collins[2] to be very similar in the character and succession of its members to the Lower Huronian of the Marquette region. The erosion plane dividing the Cobalt series and the older rocks in northern Quebec passes southward beneath the Cobalt series in the Cobalt district, and beneath the Bruce series in the Lake Huron district. It may safely be stated, therefore, that the Mattagami series is of pre-Bruce age, and therefore probably pre-Lower Huronian, and that it antedates the Bruce by an interval sufficient for orogenic forces to raise a mountain range of unknown height, and for the forces of erosion to reduce this range toward its southern side at least where the Bruce series was deposited, nearly to base-level.

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[1] W. H. Collins, *Geol. Surv. Can., Museum Bulletin No. 8*, 1914.

[2] W. H. Collins, memoir in preparation.

NEMENJISH-GRENVILLE SERIES

A series of rocks which are the metamorphosed equivalents of clastic sediments has been termed the Nemenjish series in the foregoing pages. They attain their largest extension in the contiguous Windy Lake and Nemenjish areas. These rocks are believed to be the northern equivalent of the Grenville series.

The primary basis for this tentative determination is petrographic. It is recognized clearly that petrographic similarities as a rule form a most insecure foundation for correlation; but the petrographic peculiarities of these rocks are so marked and so different from those of any other rocks observed by the writer in the pre-Cambrian of Ontario or Quebec that they afford unusually good evidence for this purpose. The major portion of the rocks, above the basal beds, are highly garnetiferous. They consist of rather fine-grained, light grey mica gneisses or schists, and greenish-black hornblende gneisses, crowded with small, light pink garnets. The garnets in the mica gneiss are usually small, 1–2 mm. in diameter; those in the hornblende gneiss usually somewhat larger, 3–5 mm. in diameter. *Garnetiferous types probably average at least 50 per cent of the total bulk.* No such bulk of garnetiferous rocks is found in any other pre-Cambrian series. Garnetiferous types, usually garnetiferous hornblende schists, occur locally in the altered basic lavas, often termed "Keewatin," and also in the Mattagami series, but invariably in minor amount, less than 1 per cent. The writer therefore considers this criterion as a reliable one for correlation purposes, until it shall have been shown that another formation with similar bulk characteristic exists in the pre-Cambrian shield.

The Grenville series extends north of the Ottawa River at Ottawa for approximately 140 miles, almost to the junction of the east and west branches of the Gatineau River. It is bounded on the north by a great batholith of granite intrusive into it. A section made by the writer in 1916 down the Gatineau River from the National Transcontinental Railway to Ottawa showed that within the boundaries mentioned above the continuity of the series is unbroken, except by relatively small granitic intrusions. Over a distance of about twenty miles south of its northern boundary the Grenville contains little crystalline limestone but is composed almost entirely of altered clastics, largely garnetiferous, of types identical or almost so with the Nemenjish series. Farther to the south, where crystalline limestone forms a large proportion of the Grenville, much of the remainder is composed of garnetiferous mica gneisses like those of the Nemenjish series.

A gap of about 140 miles exists between the Nemenjish series and the Grenville, occupied by a great batholith or batholithic complex of granite, which has an east-west extension from near the Bell River at least to Lake St. John, about 250 miles. The correlation of the two series across this belt of granite would appear at first sight a hopeless task; but it is rendered possible by the fact that the eastern end of the batholith is not deeply eroded, in fact is apparently barely unroofed. Across its whole width[1] thousands of inclusions of the Nemenjish or Grenville rocks are present, of all sizes and in all stages of digestion. These are so numerous that it is rare to find a single small outcrop of granite without undigested inclusions whose original nature is recognizable. In size the inclusions vary from small lumps a few inches or feet in diameter to large bodies several miles in length, which are probably true roof pendants. In freshness they vary from sharp-angled bodies with little or no trace of the solvent action of the granite to completely dissolved forms now represented by garnetiferous micaceous bands in the gneiss. A very characteristic trade-mark of the interaction of granite and sediment is the presence of garnet, which seems to have dissolved during the digestion of the sediment and subsequently to have recrystallized with little or no change. The formation of such digested products is so well shown in all its stages that even the end products of the reaction might safely be taken as evidence of the former presence of the sediments; but it is not necessary to rely on these as there is a sufficiency of the comparatively unaltered fragments for purposes of recognition. The highly garnetiferous character of the greater number of them renders their derivation from the Nemenjish or the Grenville series almost indubitable.

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[1] The sections studied by the writer, where such large numbers of garnetiferous inclusions were observed, were those of the St. Maurice River, from the Transcontinental Railway to Sandy Beach Lake, and thence northward across the Height of Land to Askitichi Lake; and from the Hudson Bay post at Kikendatch across to the headwaters of the Gatineau, and down the Gatineau. Farther to the west erosion appears to have removed greater thicknesses of granite; correspondingly the number of inclusions become smaller toward the west, and the proportion of those which have undergone complete or fairly complete digestion increases.

Summary.—The writer bases the correlation of the Nemenjish series with the Grenville series on the following facts: (1) The Nemenjish series possesses unusual petrographic characteristics, in that approximately 50 per cent of the rocks of the series are garnetiferous. (2) The granite batholith separating the Nemenjish and the Grenville series is loaded with recognizable inclusions of these peculiar garnetiferous schists. (3) The composition of the Grenville on the southern border of the granite batholith is identical with that of the Nemenjish series, i.e., garnetiferous mica and hornblende gneisses, with a little crystalline limestone. This passes to the south into Grenville of normal composition by increase in the amount of limestone, without much change in the character of the altered clastic members.

Relations to older formations.—The relation of the Nemenjish series to the lava series appears to be one of perfect structural conformity, although this determination is weakened by the fact that the contact was observed at one place only. As described, the sediments were found resting on the old surface of a basaltic lava flow, and with the same dip and strike as the lava. At the contact the sediments were thin beds similar to the tuffs elsewhere observed interbedded with the lavas; but these became mingled with beds of sediments similar to the overlying material a short distance above the base, and within a few hundred feet were entirely replaced by them. When these sediments were first seen, it was supposed that they probably belonged to the Mattagami series, and a very careful search was made along the contact with the lavas for evidences of unconformity, but none were found. There is not a trace here of the conglomerate which uniformly lies at the base of the Mattagami series, and appears to be at least 300 feet thick wherever it has been possible to measure it. There is no evidence of the presence here of any large fault, which might have brought the two series into intimate contact. It would appear therefore as if there was no discordance, structural or erosional, between the sedimentary series and the underlying extrusive rocks.

The problem presents itself, however, of explaining why the Nemenjish sediments here rest upon basalts, which have been shown to form elsewhere the basal rocks of the lava series, rather than upon its higher members. On the creek flowing from Little Nemenjish Lake to Obatogamau Lake, five miles to the east, the sediments overlie andesites, although the contact is not exposed.

Two hypotheses present themselves. There may have been a period of erosion intervening between the extrusion of the lavas and the deposition of the sediments, so that where the sediments rest on the lower members the younger lavas may have been removed by erosion; or the younger lavas may never have been extruded in these localities. The first hypothesis appears inadmissible, on account of the perfect conformity and lack of any trace of basal conglomerate or coarse basal sediments. If the second hypothesis be true, then some of the lower beds of the Nemenjish series must be equivalent in age to the upper lava flows, unless conditions were such that no sediment was deposited during the period intervening between the extrusion of the earliest and latest lavas. We might therefore expect to find at some point an interbedding of the sediments with the higher lava flows. This is actually the case on Kaopatina Lake, where a thin flow of rhyolite porphyry in interbanded with the sediments. In this case, the beds with which the flows are interbanded are not of true clastic material, but appear to be made up in part of cherty material, perhaps a chemical sediment, and in part of fine-grained, rather basic material, perhaps volcanic dust or the first products of erosion of the lava fields. In the critical section of the Opawika River above Kaopatina Lake, beds of similar composition were observed to lie at the base of the Nemenjish series, and to grade up into it by a gradual increase in the proportion of normal clastic material.

It seems probable therefore that the whole region was not covered by uniform sheets of lava of the same composition, but that as might be expected, the extrusions were more or less localized, so that the Nemenjish series may lie from place to place on different types, but still maintain conformable relations. Further, it appears that the sedimentation was slight during the whole extrusive period, and largely confined to deposits directly or indirectly from volcanic sources. Lava flows may be interbanded with these sediments, but the extrusion of these was complete before the true clastics became large in amount, as the two have never been found interbanded.

Relations to younger formations.—Since the Nemenjish series rests conformably on the lavas in the Windy Lake area, and the Mattagami series rests unconformably on the lavas in the Brock and other areas, it might be supposed that the Mattagami series is younger than and unconformable on the Nemenjish series. This conclusion assumes that the lavas in the different areas are of the same age. Direct field evidence bearing upon the relation of the two sedimentary series is very scanty. The only areas furnishing such evidence are the Kenoniska and Lucky Strike areas, where garnetiferous mica schists are found lying between the Mattagami basal conglomerate and the underlying lavas. The petrography of these rocks makes their correlation with the Nemenjish seem probable, and they lie unconformably beneath the Mattagami series.

The Nemenjish-Grenville series is intruded by all the plutonic rocks of the region, and is therefore older than all. An older granite intrudes it in the vicinity of Lake St. John. Later, it was cut by great masses of anorthosite. Finally, it was cut and, in this region, almost entirely stopped away and digested by the great batholithic intrusions of granite which followed the deposition of the Mattagami series.

LAVAS

The lavas of the region under discussion appear to be of a single age, so far as the evidence at hand indicates. They are very similar in their petrographic character and in the extent of their metamorphism. Wherever their succession has been worked out, it is the same; basaltic lavas form the lowest exposed beds, overlain successively by andesitic lavas, andesitic tuffs, and rhyolitic lava or tuff.[1] Wherever sediments of Nemenjish age have been found the lavas underlie them conformably. Wherever patches of the Mattagami series occur, they overlie the lavas with unconformity. Wherever anorthosite masses outcrop, they intrude the lavas.

As these lavas, like the Mattagami series, underlie the great erosional peneplain that underlies the Cobalt series, it is possible that they are to be correlated with the lavas in the Cobalt district, which are there known as "Keewatin" and which occupy a similar stratigraphic position. There is as yet, however, little or no evidence for correlating these lavas with the Keewatin of the north and south shores of Lake Superior. The local name of Abitibi volcanics will therefore be extended to apply to the lavas in this whole region. This name was first applied by M. E. Wilson in 1909 to the lavas in the Kewagama map-area, in the southwestern part of this region.

ANORTHOSITES

Anorthosite and anorthositic gabbro do not appear to any large extent within the region under discussion. A mass of considerable size is found on the Bell River, near Mattagami Lake, another on Chibougamau Lake. Smaller masses are found on the Opawika and Chibougamau rivers; there is an immense mass in the vicinity of Lake St. John. To the east and south of Lake St. John, the amount of anorthosite is much larger; it is also present in large amount in the Adirondacks.

Since anorthosite may be formed as a differentiate of any gabbroid magma under suitable conditions, and since it so happens that the anorthosite masses are not as a rule in contact with a sufficient number of sedimentary formations for their age to be closely determined there is little or no evidence that they may not be of more than one age. However, the occurrence of such great masses of anorthosite has been rare throughout geologic history. Hence it is considered highly probable that all of the anorthosite belongs to a single period of igneous activity and owes its origin to some common cause.

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[1] It may be here mentioned that the writer's work of 1917–18 has shown that the simple succession described for the lavas of northern Quebec does not prevail in the Montreal River district of northern Ontario.

The age of the anorthosite, while not definitely fixed, may tentatively be placed as post-Grenville and pre-Mattagami. In the Lake St. John district it has been found to intrude the Grenville, and also to intrude an earlier granite which also intrudes the Grenville. It is itself intruded by the later granite that cuts the Mattagami series. It has never been found in direct contact with the Mattagami series. A mass of anorthositic gabbro on the Bell River intrudes the Abitibi volcanics but does not rise as high as their contact with the Mattagami series. In the Lucky Strike area a single pebble of what was supposed to be anorthosite was observed in the basal conglomerate of the Mattagami series. This pebble could not be got out of the matrix for microscopic study, however, so that its exact determination is uncertain. The age of the anorthosite can, therefore, only be placed tentatively as pre-Mattagami.

GRANITES

In the vicinity of Lake St. John, J. A. Dresser[1] has reported the presence of granites both earlier and later than the anorthosite there. To the northwest of the lake all the granite observed is later than the anorthosite. To the south and east of the lake, Adams[2] has reported that the granite is earlier than the anorthosite. In New York state, Cushing, Kemp, and Smyth state that the anorthosite is later than the gneisses which intrude the Grenville series. The existence of granites of two ages therefore seems to be fairly definitely established. The earlier of these seems to have been confined in its distribution to the south and east of Lake St. John; in age it postdates the deposition of the Grenville series and antedates the intrusion of the anorthosite masses. The later granite was intruded mainly throughout the region to the north and west of Lake St. John, though it is also found in small amount to the south and east. In age it is pre-Cobalt, but is later than the anorthosite intrusions and the deposition of the Mattagami series.

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[1] *Geol. Surv. Can., Mem. No. 92*, 1916.

[2] *Geol. Surv. Can., Ann. Rept., New Ser.*, VIII (1897), Part J.

[*To be continued*]